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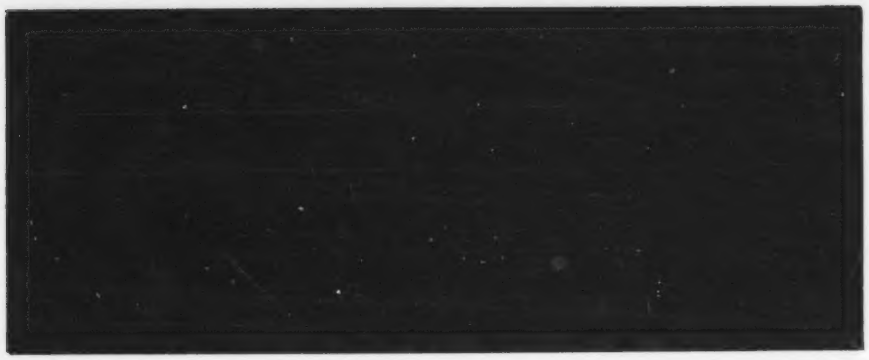

Technical/Final Report
to
Saskatchewan Agriculture Research Fund

Effect of Season and Weather on Growth Rate of Bulls in the Saskatchewan Bull Test Station

S-86-01-0048
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Final Report, SARF S-86-01-0048

Effect of Season and Weather on Growth Rate of Bulls
in the Saskatchewan Bull Test Station

retitled

FEED INTAKE OF GROWING BULLS DURING SEVERE WINTERS

Executive Summary

Attached

Technical Report

Attached

Papers and Talks

N.F. Cybaluk and G.I. Christison. 1988. Performance of growing bulls and horses in a severe winter. Livestock Environment III, Proceedings of the Third International Livestock Environment Symposium, Toronto.

N.F. Cybaluk and G.I. Christison. 1988. Performance of growing bulls and horses in a severe winter. Department of Animal and Poultry Science Research Report, University of Saskatchewan. (A lay language version of the Toronto paper).

G.I. Christison, N.F. Cymbaluk and H.H. Nicholson. 1989. Feed intake of growing bulls during severe winters. Canadian Journal of Animal Science, submitted. (Very similar to the SARF technical report).

A lay language version of the technical report will also be prepared as a Department of Animal and Poultry Science research report.

Expenditures

Sent previously, copy attached.

Personnel Involved

G.I. Christison	
N.F. Cymbaluk	8.3% of salary
H.H. Nicholson	
H. Seida	16.7% of salary
J.A. de Gooijer	
F.E. Teitge	

Valuable Equipment Purchased

None

Executive Summary, SARF S-86-01-0048

FEED INTAKE OF GROWING BULLS DURING SEVERE WINTERS

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ABSTRACT

Eight years of bull test station data were used to assess the effect of winter weather on the feed intake of cattle. Rates of intake and gain were similar to values reported from milder climates. Changes in air temperature explained 5% of the variation in average monthly feed intake but explained only 3% of the day to day changes. A drop in temperature from 0 to -15°C caused a 5% increase in feed intake. Other conclusions were that silage did not reduce intake at low temperatures and that European breeds showed a slightly greater increase in intake in the cold than did British breeds.

SUMMARY

Eight years of data from the Saskatchewan bull test station were analyzed to establish the effects of daily and monthly climatic values during winter on the voluntary intake and performance of well fed growing bulls. Starting in the fall, young bulls were on test for 140 days in drylot pens with bedded, open-front sheds and windbreak fences. They were weighed at 28-d intervals. On a dry matter basis the diet contained 50% cereal silage and 50% concentrate with a calculated digestible energy content of 3.06 Mcal/kg dry matter (68% TDN).

There was considerable year to year variation in weather. For example, in January the mean temperature ranged from -26°C to -7°C. Therefore, current conditions should be considered in any management program rather than relying on calendar averages.

Rates of gain and intake were similar to those found by others. This suggests that the prairie climate caused no dramatic performance differences between our cattle and those reared in milder regions. On a weight-scaled basis, bulls grew slightly faster (approximately 1% per 1°C decrease) at cold temperatures and were slightly more efficient (approximately 0.5% per 1°C).

As expected, animals ate more as they become heavier and older. To remove the effect of body size on intake, daily dry matter intake was scaled to body weight. The average intake was 2.2 kg/100 kg body weight. Weight-scaled intake fell as the animals became older. Secondary to the age effect, intake was 5% higher at -15°C than at 0°C.

Under bitterly cold conditions, greater effects on intake might have been expected, but there was no disproportionately greater increase in intake below -20°C. Additional feed should therefore be supplied proportionately in all

temperature ranges.

Cattle that are not full fed or which receive poorer quality feed need much greater increases in energy intake to offset cold than described here.

Days-on-test explained more of the monthly variation in intake than did temperature which was responsible for approximately 5% of the monthly differences. Temperature variation was greater from day to day than month to month so that daily temperature changes explained only 3% of daily intake variation. Changes in feed allowances should therefore be based on weather for the preceding month rather than the preceding day.

Only minor differences in intake were caused by wind or rain in these facilities which provided good wind and rain protection.

Properly made silage does not reduce dry matter intake. But in severe cold less may be eaten if silage freezes in the feed bunk. In 1978-79 the bulls were fed hay and concentrate in a 45:55 ratio rather than the 50:50 dry matter ratio of silage and concentrate in other years. Intake was higher in the hay year, but low temperatures affected intake similarly on both roughages. Therefore, silage fed two times per day to provide half of the diet dry matter is not likely to reduce intake at low temperatures.

Only four breeds were represented in a large number of single-breed pens. These were Angus, Charolais, Hereford and Simmental. There were no significant differences among the breeds in weight-scaled gain, but the Angus breed had a higher weight-scaled intake than the other breeds. The Angus and Hereford bulls increased feed intake to a lesser extent in response to declining air temperature than did Charolais or Simmentals. The values were equivalent to increases in intake of 2.1, 2.9, 5.0 and 6.4 %, respectively, for the Angus, Hereford, Charolais and Simmental breeds when air temperature fell from 0 to -15°C.

Technical Report, SARF S-86-01-0048

FEED INTAKE OF GROWING BULLS DURING SEVERE WINTERS

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ABSTRACT

Test station data was collected for eight winters on twelve pens of young bulls. Dry matter (DM) intake was recorded daily for 140 d and was correlated with climatic data. The bulls were weighed every 28 d and monthly gain and intake were related to monthly climatic means. Rates of intake and gain were similar to values obtained in milder climates. Linear models for the effects of several variables on weight-scaled monthly intake were considered by stepwise procedures which indicated that days on test gave the highest R^2 and that most climatic variables explained little additional variation. Linear models for daily data gave lower R^2 than did monthly data. Regressions indicated that for every 1°C decline in air temperature weight-scaled DM intake would increase by 0.29% based on daily values or 0.43% based on monthly values. These are equivalent to consumption increases of 4.3% and 6.5%, respectively, in response to a fall in temperature from 0 to -15°C. Weight-scaled intake was also evaluated in three temperature ranges and was approximately 3% higher between -10°C and -20°C than above -10°C. There was no notably greater increase in intake below -20°C. Other conclusions were that silage was unlikely to reduce intake at low temperatures and that European breeds showed a greater increase in weight-scaled intake in response to cold than did British breeds.

BACKGROUND AND OBJECTIVES

Reviews of the effects of cold on intake by beef cattle conclude that intake generally increases in response to decreasing air temperatures (NRC 1981; Young 1987). But feedlot data collected over a number of years in Saskatchewan found intake to be low in the depth of winter (Milligan and Christison 1974). These contradictory results support the epilogue of the National Research Council review (NRC 1981) which noted that there was a need for research to establish voluntary feed intake patterns in different environments and to predict responses to fluctuating temperatures. Daily climatic and feed intake data from the Saskatchewan bull test station for cattle which were of similar type from winter to winter and where diets of identical formulation were fed in consecutive years. These data were analyzed to establish the effects of daily and monthly climatic values on the voluntary intake and performance of well fed growing bulls exposed to continuing outdoor cold.

EXPERIMENTAL METHODS

The bull test station at Saskatoon has twelve 21 x 24-m drylot pens with 7 x 11-m south-facing, open-front sheds in a corner away from the 18-m feedbunks. The area within and in front of the sheds is bedded with fresh straw twice weekly and after snow falls. The pens are served from a central feeding alley and are surrounded by a 3-m high, 20%-porosity windbreak fence. Climatic data are collected at the Saskatchewan Research Council weather station 450 m away.

Bulls between 167 and 256 days of age entered the national testing program in the fall and were usually penned in groups of 23 to 27. During a 28-d adaptation period the ration was adjusted until the bulls were eating the test diet free choice. They were then on test for 140 d and were weighed at 28-d

intervals, giving five 28-d periods. Feed was provided at 0800 and 1600 h each day. The amount offered each morning was half of the daily quantity which the stockman believed would be almost completely consumed by the following morning. Unconsumed feed was weighed weekly and prorated on a daily basis. Because the quantity of feed remaining in the feed bunk in the morning was influenced by the weather the previous day, the daily feed data were advanced by one day before correlating with climatic variables. Because feed records were pen-based, the experimental units were pens not individual animals. Daily feed intake per animal was calculated as total feed divided by the number of animals in the pen. The mean animal weight for each day was calculated as the initial weight for that period plus the average daily gain of the pen times the appropriate number of days.

In this paper, winters are identified as the year they began. Thus, 1974 indicates the period from fall 1974 to spring 1975. Because of differences of feed ingredients and starting dates, yearly data were considered in three subsets: 1980-1985, 1974-1976 and 1978 by itself when hay was fed instead of silage. In the five winters 1980-1985 (1983 unavailable), the 140-day test began, on average, on November 8. On a dry-matter (DM) basis the diet comprised 50% cereal silage (of 70% moisture), 40.5% rolled oats, 7.5% canola meal and 2% vitamin-mineral premix. In the three winters 1974-1976 the average starting date was December 2. The diet contained 50% brome-alfalfa silage, 43% rolled oats, 5% rapeseed meal and 2% vitamin-mineral premix. In the winter of 1978 the test began on December 5 and the diet was 45% brome-alfalfa hay, 41% rolled oats, 5% canola meal, 2% beet pulp, 2% tallow, 2% vitamin-mineral premix. All of the diets had a calculated digestible energy content of 3.06 Mcal kg^{-1} DM.

Statistical analyses included repeated measurements analysis of variance

and covariance, linear and multivariate regression analyses, and correlation analyses. The general linear models procedure of SAS (1985) was used. Means were compared by the Waller-Duncan k ratio test (Steel and Torrie 1980). Slopes and intercepts of linear equations were compared by the method of Kleinbaum and Kupper (1978).

RESULTS AND DISCUSSION

Climate

The winter climate of the Canadian prairies is characterized by temperatures well below -20°C, resulting from Arctic air streams which prevail for days or weeks. When Pacific air moves in, temperatures rise to near freezing. Thus, the mean January temperature on the prairies is an average of intermittent periods which are very cold or relatively mild (Hare and Thomas 1979). Such a temperature pattern offers the opportunity to study daily and monthly climatic effects on animals and to examine concurrently the short term as well as longer term animal responses. Mean monthly climatic values (Table 1) show appreciable differences between the sets of years. There was also considerable year to year variation in climate. For example, in period three the mean temperature was -26.1°C in 1981 but was -7.4°C in 1984. This suggests that current conditions should be considered in any management program, rather than relying on calendar averages.

Period Performance

Body weight of the bulls in 1980-1985 increased from month to month although average daily gains (ADG) were variable from period to period (Table 2). Each monthly value is within the range depicted in the NRC review (1987) concerning feed intake of beef cattle. Animals went on test at lighter weights

in 1974-1976 than in 1980-1985. The apparent higher ADG in the later years (Table 2) resulted from a change toward faster-growing breeds. Koots et al. (1988) have shown that ADG for individual breeds (except Angus) did not increase significantly in the period 1964-1985, but that start-of-test weights increased for the five breeds in that study.

In both sets of years, daily DM intake increased as the animals grew heavier and older rather than plateauing with time as did intake of a large number of feedlot steers (Hicks et al. 1987). Actual DM intakes in 1980-1985 are at the upper end of the range for DM intake depicted by NRC (1987) and Hicks et al. (1987). This in itself suggests that environmental factors caused no dramatic intake differences between our cattle and those reared in milder climates.

To avoid the confounding effect of weight on intake, daily DM intake was scaled to body weight. When daily intake was scaled to 100 kg body weight (BW), intake fell consistently with time in both sets of winters (Table 2). This does not confirm the results of Milligan and Christison (1974) who found weight-scaled intake to fall from 2.3 kg 100 kg^{-1} BW in November to 2.0 in January, but then to rise to 2.4 kg 100 kg^{-1} BW in March. The mean weight-scaled intake for 1974-1976 was 14% higher (Table 2) than from 1980-1985. This difference most probably resulted from an overestimation of silage DM percentage in 1974-1976 with a consequent 17% overestimation of daily DM intake.

Period Correlations for Performance

Simple correlations across periods of performance variables with days on test, body weight and air temperature (Table 3) generally indicated that days on test and weight had similar effects--as would be expected because the bulls

grew heavier with age. For all performance variables, days on test had a higher correlation than did temperature, and thus explained more of the period to period variation than did temperature. This was also true of weight-scaled data (Table 3) where temperature variation explained approximately 5% of the period variation.

With feedlot cattle the power function relating DM intake to BW changed from 1.02 for the first 14 d to about 0.47 beyond 56 d on feed (Hicks et al. 1987). In the present experiment, preliminary calculations (not shown) indicated that scaling to $BW^{1.0}$ gave correlation coefficients for single and multiple variable equations which resulted in R^2 values approximately 50% higher than if $BW^{0.75}$ was used as the scaling factor. Daily intake was therefore scaled to 100 kg BW.

On a weight-scaled basis, in both sets of winters (Table 3), bulls grew slightly faster at cold temperatures (approximately 1% faster per 1°C), ate slightly more (0.4% per 1°C) and were slightly more efficient (approximately 0.5% per 1°C).

A stepwise procedure (SAS 1985) was used to consider linear models for period data with several variables which affected weight-scaled intake. For 1974-1976, days on test gave an R^2 of 0.088 which increased to 0.153 when wind speed was also included. The further addition of temperature and precipitation only increased the R^2 to 0.155. If days on test was not included, the three climatic variables had an R^2 of 0.086. Global solar radiation data was not available in 1974-1976. For 1980-1985, days on test had an R^2 of 0.485 (Table 4) and the stepwise addition of precipitation, global solar radiation, wind speed and temperature only increased the R^2 to 0.499. If days were not included, radiation alone (R^2 = 0.351, with r negative) (Table 4) explained virtually all of the difference which could be explained by radiation plus

temperature, wind speed and precipitation. This was, in part, because radiation increased for the final 96 days of the study whereas mean temperature plateaued from December to February (Table 1). Gonyou and Stricklin (1984) found that increasing age and daylength from January to May did not affect the daily duration of feeding by cattle in these facilities. This indicates that on a weight-scaled basis feeding duration declined with increasing photoperiod. In the present study, weight-scaled DM intake decreased 4% per 28 d of increasing radiation. Our findings are counter to the conclusion of a number of studies that decreasing light exposure decreases intake of cattle fed free choice (Young 1987). Global solar radiation may itself not be a direct cause of intake variation, but may simply be an index of "winter" or acclimatization.

Daily Correlations for Weight-scaled Intake

Daily DM intake is under the animal's control and can be monitored daily. It is an important production variable which affects the animal's ability to meet its requirements for maintenance--including cold resistance--and growth. It was therefore of interest to correlate weight-scaled intake with daily environmental values and to compare these values with those for data derived from period means (Table 3). In general, daily variation in intake and climate resulted in an appreciably smaller R^2 for models derived from daily data despite the 28-fold increase in data points in the equation. This is in agreement with the suggestion (NRC 1981) that intake depends on the general state of the environment rather than on daily values and that adjustment for environmental effects is more accurate if weekly or monthly environmental information is used (NRC 1987).

Temperature alone explained only 3% of the variation of intake on a daily basis and, after the radiation effect was included, all of the other climatic

values considered added little explanation to the models (Table 4). When temperatures below and above -10°C were considered separately, R^2 values were not improved. The slopes of the regressions for temperature are negative and indicate that for every 1°C decline in temperature weight-scaled DM intake would increase by 0.29% for daily values, or by 0.43% for monthly values. These are equivalent to increases in intake of 4.3 and 6.5%, respectively, in response to a drop in temperature from 0 to -15°C and are very similar to the 6.5% increase in intake suggested by NRC (1981) when temperature drops from 0 to -15°C (assuming that the effect at -15°C is midway between those indicated for the two ranges -5 to -15°C and below -15°C). A minimal effect would be expected because the bulls were constantly exposed to progressively colder temperatures in the fall and early winter. The increased intake might be in compensation for the lower digestibility of feedstuffs found at low temperatures (NRC 1981; Young 1987). These full fed bulls would continue to acclimatize throughout the trial and may never have been exposed to temperatures below their lower critical temperature which would range from -10° C in November to well below -30°C in February (NRC 1981). This is consistent with the efficient gain noted in Table 2.

Because of the potential for erratic results with daily data, Senft and Rittenhouse (1985) proposed that temperatures from a number of previous days be considered collectively. When calculations similar to those reported in Table 4 were repeated using mean temperature accumulated for the preceding 2, 3, 4,...14 d for 1980-1985, the highest R^2 was found for a single day's data Table 4). Calculations based on combining the preceding 2 d gave an R^2 almost as high, but the R^2 declined for any longer period up to a cumulative 14-day lag. This does not support Senft and Rittenhouse's proposal (1985) which indicated that R^2 would have maximized with a 9- to 12-day cumulative lag.

Climatic Ranges

The regression equations (Tables 3 and 4) evaluated the effects of climatic variables over the whole range encountered. However effects on intake might only be expected at the low end of the range. Climatic ranges which we used previously for horses were selected (Cymbaluk and Christison 1988). The three temperature ranges were: above -10°C, from -10 to -20°C, and below -20°C. The two precipitation ranges were a trace or less (under 0.25 mm d^{-1} rainfall equivalent; Hare and Thomas 1979) or more than a trace. The two ranges of wind speed were above or below 4.34 m s^{-1}.

The data in Table 5 are least square means of weight-scaled feed intake using days on test as a covariate. The results are similar both quantitatively and statistically to those obtained without age adjustment. Yet, because time is important in affecting intake, as already discussed, it was desirable to remove age to allow an expression of climatic influences alone.

Data from both sets of winters show that intake differed ($P<.05$) at each of the three temperature ranges. However the change in weight-scaled intake from 2.58 to 2.54 in 1974-1976, or from 2.17 to 2.19 kg 100 kg^{-1} BW in 1980 to 86 (Table 5) is of little biological importance. No abrupt increase occurred in either of the lower temperature ranges considered. Such an increase would not necessarily occur at the lower critical temperature because heat production could be increased (at the expense of tissue deposition) without any change of intake--especially if intake was already maximal.

A reasonable generalized conclusion is that temperatures below -10°C result in increased DM intake and that if temperature falls from 0 to -15°C, the increase is of the order of 3%. This is comparable to the 6.5% increase in response to a temperature shift from 0 to -15°C indicated by NRC (1981) and is

consistent with the values (4.3 and 6.5%) calculated from daily and monthly regressions in the preceding section. Young horses in adjacent pens without sheds decreased intake slightly in the colder temperature ranges (Cymbaluk and Christison 1988). The 10% higher feed adjustment factor for growing cattle below -15°C, compared to 0°C, suggested by NRC (1981) may be too high for acclimatized animals. The bulls ate at rates consistent with those determined by others under more temperate conditions (NRC 1987; Hicks et al. 1987) so DM intake may already be maximal.

When wind or rain were considered alone (Table 5), differences in intake were found for the two ranges of both variables, but the direction of the changes was opposite in the two sets of years. Again, the differences were of minor biological importance. Wind does have a greater effect on cattle at -30°C than 0°C (Christopherson et al. 1979) but our pens and fences provided good wind protection, particularly because the pens were small so the bulls were always close to the shelter. Such wind protection is probably adequate for the conditions encountered. It is impossible to indicate whether the sheds are a necessary addition.

When wind and temperature or precipitation and temperature were considered together, there were significant differences caused by the presence or absence of wind or snow at temperatures below -10°C but these were small and inconsistent with temperature ranges for the two sets of years. Gonyou and Stricklin (1984) noted that stormy weather reduced eating behavior, but it was not possible to define storms unambiguously enough to retrieve them from our climatic data set.

Hay versus Silage

The 1987 NRC review of factors affecting feed intake of beef cattle

indicates that, when fermentation is appropriate and the material is not unusually wet or dry, DM intake is unaffected by feeding silage. Under severe cold conditions, however, silage intake may be limited if it begins to freeze while in the feed bunk.

In 1978 the bulls in the station were fed hay and concentrate in a 45:55 DM ratio rather than the 50:50 DM ratio of silage and concentrate of other years. When the slope (-0.00393) and intercept (2.491) for the regression of weight-scaled DM intake against daily temperature for 1978 were compared with the 1980-1985 values (Table 4) the intercept, or intake at 0°C, was higher ($P<.001$) in the hay year. This is consistent with results from northern Ontario, where overwintered beef cows consumed less DM from grass silage than from hay (Jordan et al. 1977). The slopes of the two lines did not differ. This indicates that the effect of air temperature on DM intake was not different for the two roughage sources. Behavioral studies showed that when bulls in these pens were fed a diet of 30% barley silage (DM basis) at 0800 and at 1600 h they had a major feeding period from 2200 to 0200 h on a day when the mean temperature was -24°C (Gonyou and Stricklin 1984). This suggests that freezing of the silage did not depress feeding behavior and supports the present conclusions. Therefore, silage fed two times per day to provide half of the diet DM is not likely to reduce intake at low air temperatures.

Breed Differences

Thirteen breeds of bulls were represented in the test station over the course of the trials, but many of the breeds did not have sufficient numbers to fill a pen. Only four breeds were represented in a large number of single-breed pens in 1980-1985. These were Angus, Charolais, Hereford and Simmental. There were no significant differences among the breeds in weight-scaled gain,

but the Angus breed had a higher overall weight-scaled intake than the other breeds (Table 6) and had the lowest efficiency of gain. When intake was regressed against daily temperatures the Angus breed had a higher weight-scaled intake than the other breeds as indicated by the higher intercept at 0°C. The slopes of weight-scaled intake against temperature (Table 6) indicate that the Angus and Hereford bulls increased feed intake to a lesser extent in response to declining air temperature than did Charolais or Simmentals. The slopes in Table 6 are equivalent to increases in intake of 2.1, 2.9, 5.0 and 6.4 %, respectively, for the Angus, Hereford, Charolais and Simmental breeds when air temperature fell from 0 to -15°C.

CONCLUSIONS

Shelter reduces cold stress even in the severest conditions to a point where well fed cattle can adapt physiologically and perform satisfactorily in terms of growth, intake and feed efficiency.

There was considerable year to year variation in weather. For example, in January the mean temperature ranged from -26°C to -7°C.

Rates of gain and intake were similar to those found in milder regions. On a weight-scaled basis, bulls grew slightly faster at cold temperatures (approximately 1% faster per 1°C decrease) and were slightly more efficient (approximately 0.5% per 1°C).

The average intake was 2.2 kg/100 kg body weight. Animals ate more as they became heavier. Weight-scaled intake fell while the test period progressed and the animals became older. Secondary to the age effect, intake increased with increasing cold and was 5% higher at -15°C than at 0°C. There was no greater increase in intake below -20°C than above it.

Days-on-test explained more of the monthly variation in intake than did

temperature--which was responsible for approximately 5% of the monthly difference. Temperature variation was greater from day to day than month to month and daily temperature changes explained only 3% of daily intake variation.

Only minor differences in intake were caused by wind or rain in these facilities which provided good wind and rain protection.

Low temperatures had similar effects on the intake of hay and silage.

There were no significant differences among the breeds in weight-scaled gain. The Angus and Hereford bulls increased feed intake to a lesser extent in response to declining air temperature than did Charolais or Simmentals. The values were equivalent to increases in intake of 2.1, 2.9, 5.0 and 6.4 %, respectively, for the Angus, Hereford, Charolais and Simmental breeds when air temperature fell from 0 to -15°C.

IMPACT

The prairie winter climate caused no dramatic performance differences between our cattle and those reared in milder regions. Because of climatic variation from year to year, current conditions should be considered in any feeding program rather than relying on calendar averages. Feeding programs which make allowance for cold should be based on the previous monthly or weekly average, not on daily temperatures.

Well fed cattle voluntarily consumed more feed as the air temperature fell. For example, feed intake increased 5% at -15°C compared to intakes at 0°C. The additional feed should be supplied proportionately in all temperature ranges. (Cattle that are not full fed or receive poorer quality feed will need a much greater amount of additional feed to offset cold).

Silage fed two times per day to provide half of the diet dry matter did not appear to limit intake at low temperatures.

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PERFORMANCE OF GROWING BULLS AND HORSES IN A SEVERE WINTER

N.F. Cymbaluk and G.I. Christison

INTRODUCTION

A book which reviewed of the effects of the environment on animal production indicated that additional information was needed on the effects of cold weather on feedlot cattle. Horses were not discussed in the review and we are unaware of other information regarding the performance of growing horses exposed to severe outdoor cold.

OBJECTIVES

To compare environmental effects on feed utilization by growing horses with beef bulls of a comparable age under similar outdoor climatic and management conditions.

MATERIALS AND METHODS

Bulls

A total of 197 bulls were penned in groups of 15 to 24 and adjusted to the test diet. On a dry matter (DM) basis, the diet had a calculated digestible energy (DE) content of 3.06 Mcal/kg DM and was composed of 50% cereal silage, 40.5% rolled barley, 7.5% canola meal plus vitamins and minerals. Feed was provided at 0800 and 1600 h daily in quantity which would be almost completely consumed by the following morning. Ten pens of bulls were studied. The main population of bulls was Angus, Charolais and Hereford but five other breeds were represented. Feed records were pen-based, thus pens were the experimental units rather than individual animals. The bulls were 195 to 284 days of age at the start of the test on November 10, 1981. They were fed diets ad libitum for 140 days and were weighed every 28 d.

Horses

Forty-two Quarter Horse or Quarter Horse-cross weanlings penned in groups of seven (usually four colts and three fillies) were adjusted to one of two main diet types. The high forage diet had a DE of 2.65 Mcal/kg DM and was composed of 73 to 77.5% alfalfa hay, 17% oats-barley (1:3), 4 to 5.5% soybean meal and vitamin-mineral supplement. The high concentrate diet had a DE content of 3.07 Mcal/kg DM and consisted of 33 to 34.25% alfalfa hay, 52.25 to 53% oats-barley (1:3), 9 to 9.75% soybean meal and vitamin-mineral supplement. Each diet was fed as 16-mm pellets to three pens of horses. Feed and water were offered ad libitum as described for the bulls. The horses had an average age of 168 d at the start of the experiment on October 20, 1981 and remained on test for 210 d. They were weighed at 14-d intervals.

Environment

Bulls were held in 21 X 24-m drylot pens which had bedded 7 X 11-m, south-facing, open-front sheds in a corner away from the 18-m feed bunk. The horses were kept in 12 X 24-m clay-base, drylot pens with a 7.5-m feedbunk. The pens were bedded at the end away from the feed bunk adjacent to the windbreak fence. The set of pens for each species was surrounded by a 3-m high windbreak fence of 20% porosity.

RESULTS AND DISCUSSION

Climate

The winter of the study was extremely cold (Fig. 1), with 40 consecutive days (except for 3 d) when the mean temperature was -20 C or lower. For these 40 d, the average minimum daily temperature was -33 C.

Animal Performance

The body weights (W) and daily gains (Fig. 1) were typical for these types and ages of bulls. Horses were heavier at 1 year of age and gained more rapidly in the previous 6 mo than reported by others for light horse weanlings fed similar amounts. Thus, the severity of this winter did not obviously reduce performance of bulls or horses fed good quality diets ad libitum. Dietary type, concentrate or forage, did not affect W of horses. Body weight increased with time for both species (Fig. 1). When expressed per 100 kg W, bull weight gains decreased with days on test whereas horse weight gains decreased until late January and then plateaued (Fig. 1). Regardless of dietary source, ad libitum fed horses consumed 37% more DE per day than the amount suggested for growth by NRC (1978). Daily DE intakes by bulls increased with days on test, and hence age and weight, from November to mid-January and decreased slightly in February (Fig. 1). DE intake may have increased as a result of the bitter January cold and the apparent February trough may represent a return to a "normal" intake. Although the horses had positive weight gains throughout the winter, intake plateaued from mid-December to mid-February concurrent with the period of severe cold (Fig. 1).

Correlations of Intake with Days on Test and Temperature

Moderate but significant correlation (r) was found between daily DE intake and number of days the animals had been on test (Table 1). Daily temperature had a smaller association with daily DE intake than did age. The slopes of the equations indicate that 1 C decrease in air temperature caused bulls to increase DE intake by .35% and for horses to decrease DE intake by .32%.

For bulls, weight-scaled DE intake had a higher correlation to days on test than to temperature (Table 1). Days on test is confounded with age and maturity but, nonetheless, time should be considered in climatic

trials even when the data are weight-scaled. The slope of the weight-scaled DE intake-temperature equation for bulls indicates that every 1 C decrease in temperature would cause intake to increase by .12%. Thus, if air temperature fell from 0 to -15 C, intake would increase by 1.8%. A simple model of weight-scaled DE intake to temperature was not significant (P=.10) for horses (Table 1). Weight-scaled DE intake in horses declined with days on test to day 140 and plateaued until day 210 (Fig. 1). This may reflect a non-specific age effect of acclimatization, increased insulation by fat and coat cover, or seasonal influences.

It is notable that the response by horses to low temperatures was in a direction opposite to that reported for cattle and for other species. Previous data collected by us indicated that weight-scaled DE intake of horses kept in an unheated barn increased with decreasing temperature to a similar extent as for cattle in the present study.

Climatic Ranges

The simple linear model described in Table 1 gives equal value to all parts of the temperature range encountered. However, some effects may occur only at the low end of the temperature range. Thermal environment can affect feed intake above temperatures defined as the lower critical temperature for feedlot steers (Young 1983). The effects of daily temperature, precipitation and wind speed on the adjusted means of weight-scaled DE intake are given in Table 2.

When exposed to daily temperatures between -10 and -20 C, bulls consumed 6.64 Mcal/100 kg W which is higher (P<.01) than the 6.49 Mcal/100 kg W consumed above -10 C (Table 2). The 2.3% increase at -10 to -20 C is consistent with the results in the previous section where an air temperature of -15 C was calculated to result in a 1.8% increase in weight-scaled DE intake. Below -20 C the further 1.8% increase in intake by bulls (from 6.64 to 6.76 Mcal/100 kg W) was not statistically significant (P=.06), but suggests that decreasing temperatures may still stimulate intake. DE intake by horses was similar below -20 C and in the -10 to -20 C temperature range (Table 2). These intakes represent a 6.1% decrease from the 7.99 Mcal/100 kg W consumed above -10 C (P<.01).

The species difference in response to severe cold is probably not due to diet composition. Silage was eaten in greater amounts by bulls in response to cold temperatures (Table 2). Horses consumed similar quantities of DE irrespective of whether they were fed forage or concentrate diets. Pelleting of both horse diets allowed maximization of intake, particularly of the high hay diet.

Above average daily wind speed had no significant effect (P>.05) on weight-scaled DE intake of bulls or horses (Table 2). Both species were protected by wind-break fences and the bulls also had sheds. These types of shelters therefore appear to be effective. Precipitation did not alter intake by either species. Bulls had overhead shelter in the loafing area but were exposed to precipitation when eating. It is unknown whether or not the sheds were necessary for the bulls.

CONCLUSIONS

Beef bulls responded to severe cold temperatures by elevating DE intake. Horses responded to similar temperatures by reducing DE intake. Horses consumed more DE per unit of body weight than cattle irrespective of the ambient temperature. Age, and thus body weight, confounded the weight-scaled DE intake response to temperature by both species. Scaling DE intake to weight showed that bulls ate .12% less DE per 100 kg W for each degree decline in temperature below 0 C and increased weight-scaled DE intake by 1.8% at -15 C. Temperature was poorly related to weight-scaled DE intake by horses. DE intakes by horses were 6.1% lower below -10 C than at temperatures above -10 C. By comparison, bulls ate 2.3 or 4.1% more DE/100 kg W at -10 to -20 C and below -20 C, respectively, than at temperatures above -10 C. Growth of bulls and horses was comparable to values reported for these types of livestock reared in other regions of the world.

IMPACT ON INDUSTRY

Cattle and horses are able to tolerate severe cold outdoor temperatures if sheltered from wind and given readily digested feeds free choice.

ACKNOWLEDGEMENTS

The project was supported by the Saskatchewan Agriculture Research Fund and the Farming for the Future program of Alberta Agriculture. The technical assistance of F. E. Teitge and J. A. de Gooijer and the provision of climatic data by R. Begrand of the Saskatchewan Research Council are gratefully acknowledged.

Table 1. Regressions of Daily Digestible Energy Intake of Growing Bulls and Horses Against Days on Test and Daily Temperature (°C).

Intake	Species	Modal	r
Digestible energy intake (Mcal)	Bulls	24.5 + .0348 Days	.40***
		25.7 - .0907 Temp	.28***
	Horses	17.0 + .0365 Days	.53***
		21.9 + .0711 Temp	.21***
Digestible energy intake (Mcal/100 kg W)	Bulls	7.58 - .01367 Days	.54***
		6.51 - .00781 Temp	.08**
	Horses	8.81 - .00905 Days	.38***
		7.80 + .00559 Temp	.05+

***, ** P<.001, P<.01, respectively
+ P~.10

Table 2. The Effects of Temperature, Wind and Precipitation on Age-Adjusted Least Square Means for Daily Digestible Energy Intake (Mcal/100 kg W) by Growing Bulls and Horses Fed Ad Libitum.

			Bulls		Horses	
Variable	Range		days[a]	DE/W	days[a]	DE/W
Temperature (°C)	> -10	-	56	6.49[y]	120	7.99[x]
	-10 to -20	-	40	6.64[x]	46	7.53[y]
	< -20	-	44	6.76[x]	44	7.52[y]
Wind (m/s)	< 4.34	-	99	6.65	136	7.75
	≥ 4.34	-	41	6.61	74	7.60
Precipitation (mm/d)	< .25	-	100	6.59	158	7.61
	≥ .25	-	40	6.67	52	7.75
Temperature (°C) and Wind (m/s)	> -10	< 4.34	36	6.47	69	8.01
		≥ 4.34	20	6.51	51	7.96
	-10 to -20	< 4.34	27	6.69	30	7.77
		≥ 4.34	13	6.59	16	7.29
	< -20	< 4.34	36	6.80	36	7.48
		≥ 4.34	8	6.72	8	7.56

[a] Number of days on which the conditions occurred

x,y For each species, means associated with different temperature ranges followed by different superscripts differ (P<.01)

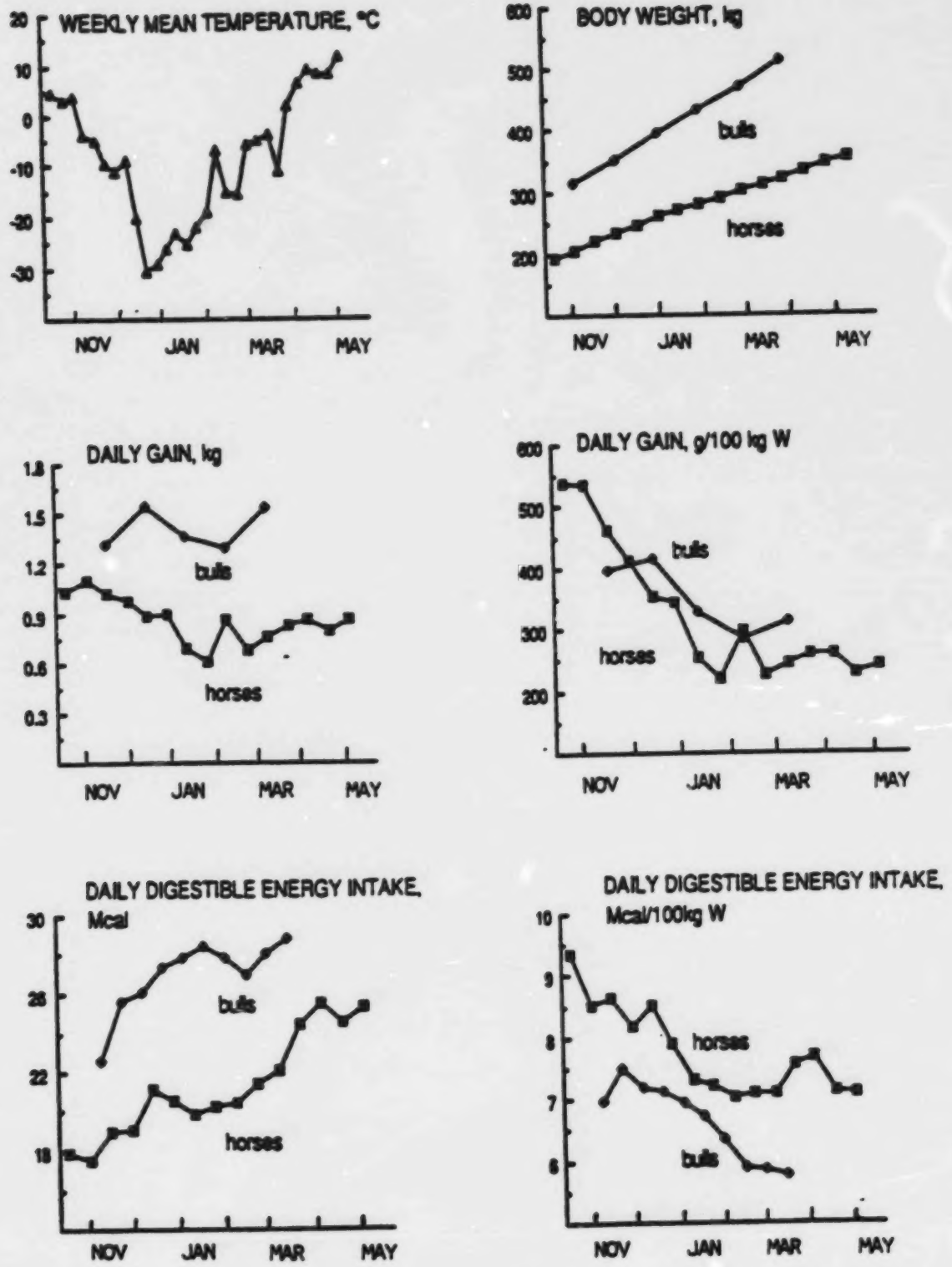

Fig. 1. Weekly temperatures and performance variables of bulls and horses reared outdoors during months of severe cold.

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PERFORMANCE OF GROWING BULLS AND HORSES IN A SEVERE WINTER

N.F. Cymbaluk G.I. Christison

A review of the effects of the environment on animal production (NRC 1981) concluded that additional information was needed on the effects of cold weather on feedlot cattle. Horses were not discussed in the review and we are unaware of other information regarding the performance of growing horses exposed to severe outdoor cold. Two trials which ran concurrently in adjacent outdoor drylot pens offered an opportunity to compare environmental effects on feed utilization by growing horses (Cymbaluk and Christison 1988) with beef bulls of a comparable age (Christison et al. 1988) under similar climatic and management conditions.

MATERIALS AND METHODS

Bulls

A total of 197 bulls were penned in groups of 15 to 24 and adjusted to the test diet. On a dry matter (DM) basis, the diet had a calculated digestible energy (DE) content of 3.06 Mcal/kg DM and was composed of 50% cereal silage, 40.5% rolled barley, 7.5% canola meal plus vitamins and minerals. Water was constantly available from heated water bowls. Feed was provided at 0800 and 1600 h daily. The amount of feed offered at each feeding was half of the daily quantity which the stockman believed would be almost completely consumed by the following morning based on the previous day's intake. Because the quantity of feed remaining in the morning reflected the effect of the previous day's weather, the feed data were advanced by one day before correlating with climatic variables. Ten pens of bulls were studied. The main population of bulls was Angus, Charolais and Hereford but five other breeds were represented. Feed records were pen-based, thus pens were the experimental units rather than individual animals. The bulls were 195 to 284 days of age at the start of the test on November 10, 1981. They were fed diets ad libitum for 140 days and were weighed every 28 d (Christison et al. 1988).

Horses

Forty-two Quarter Horse or Quarter Horse-cross weanlings penned in groups of seven (usually four colts and three fillies per pen) were adjusted to one of two main diet types. The high forage diet had a DE of 2.65 Mcal/kg DM and was composed of 73 to 77.5% alfalfa hay, 17% oats-barley (1:3), 4 to 5.5% soybean meal and vitamin-mineral supplement. The high concentrate diet had a DE content of 3.07 Mcal/kg DM and consisted of 33 to 34.25% alfalfa hay, 52.25 to 53% oats-barley (1:3), 9 to 9.75% soybean meal and vitamin-mineral supplement. Each diet was fed as 16-mm pellets to three pens of horses. Feed and water were offered ad libitum as described for the bulls. The horses had an average age of 168 d at the start of the experiment on October 20, 1981 and remained on test for 210 d. They were weighed at 14-d intervals (Cymbaluk and Christison 1988).

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Environment

Bulls were held in 21 X 24-m drylot pens which had 7 X 11-m, south-facing, open-front sheds in a corner away from the 18-m feed bunk. The area within and 5 m in front of the shed was bedded with fresh straw twice weekly and after snowfalls. The horses were kept in 12 X 24-m clay-base, drylot pens with a 7.5-m feedbunk. There were no sheds. The pens were bedded at the end away from the feed bunk adjacent to the windbreak fence. Fresh bedding was provided as for bulls. The set of pens for each species was surrounded by a 3-m high windbreak fence of 20% porosity. One such fence separated the two species. Climatic data were collected at the Saskatchewan Research Council weather station 400 m from the feedlot.

Statistics

Statistical analyses included analysis of variance and covariance for unbalanced data, regression and correlation analyses. Linear equations were compared using the method of Kleinbaum and Kupper (1978). Three temperature ranges were selected with the separation points at -10 and at -20 C. Days in which precipitation exceeded a trace (≥.25 mm/d; Hare and Thomas 1979), and days in which the mean daily wind speed equalled or exceeded 4.34 m/s were also considered separately. Since days on test and weight affected intake and were confounded with age, age was used as a covariate in the analysis of weight-scaled DE intake.

RESULTS AND DISCUSSION

Climate

Saskatoon (52°N, 107°W) has a wide annual temperature range. Precipitation is low, winds are moderate and clear skies predominate year round (Hare and Thomas 1979). The winter of the study was extremely cold (Fig. 1), with 40 consecutive days (except for 3 d) when the mean temperature was -20 C or lower. For these 40 d, the average minimum daily temperature was -33 C. Weekly mean wind speed ranged between 3.0 and 5.0 m/s and averaged 4.04 m/s; weekly mean precipitation was usually less than .8 mm/d and averaged .34 mm/d.

Animal Performance

The body weights (W) and daily gains (Fig. 1) were typical for these types and ages of bulls (Rahnefeld et al. 1987; NRC 1987). Horses were heavier at 1 year of age and gained more rapidly in the previous 6 mo than reported for light horse weanlings fed 20 to 30% above NRC energy requirements (Boren et al. 1987; Szcaurek et al. 1987). Thus, the severity of this Saskatchewan winter did not obviously reduce performance of bulls or horses fed good quality diets ad libitum. Dietary type, concentrate or forage, did not affect W of horses. Body weight increased with time for both species (Fig. 1). Daily gains by bulls derived on 28-d intervals were inconsistent among periods. The pattern of 28-d interval ADG of bulls was similar to that reported by Rahnefeld et al. (1987). Daily gains by horses decreased from October to February, then slowly increased. When expressed per 100 kg W, bull weight gains decreased with days on test whereas horse weight gains decreased until late January and then plateaued (Fig. 1). We have previously reported a negative correlation between daily gain and age in weanling horses (Cymbaluk et al. 1988).

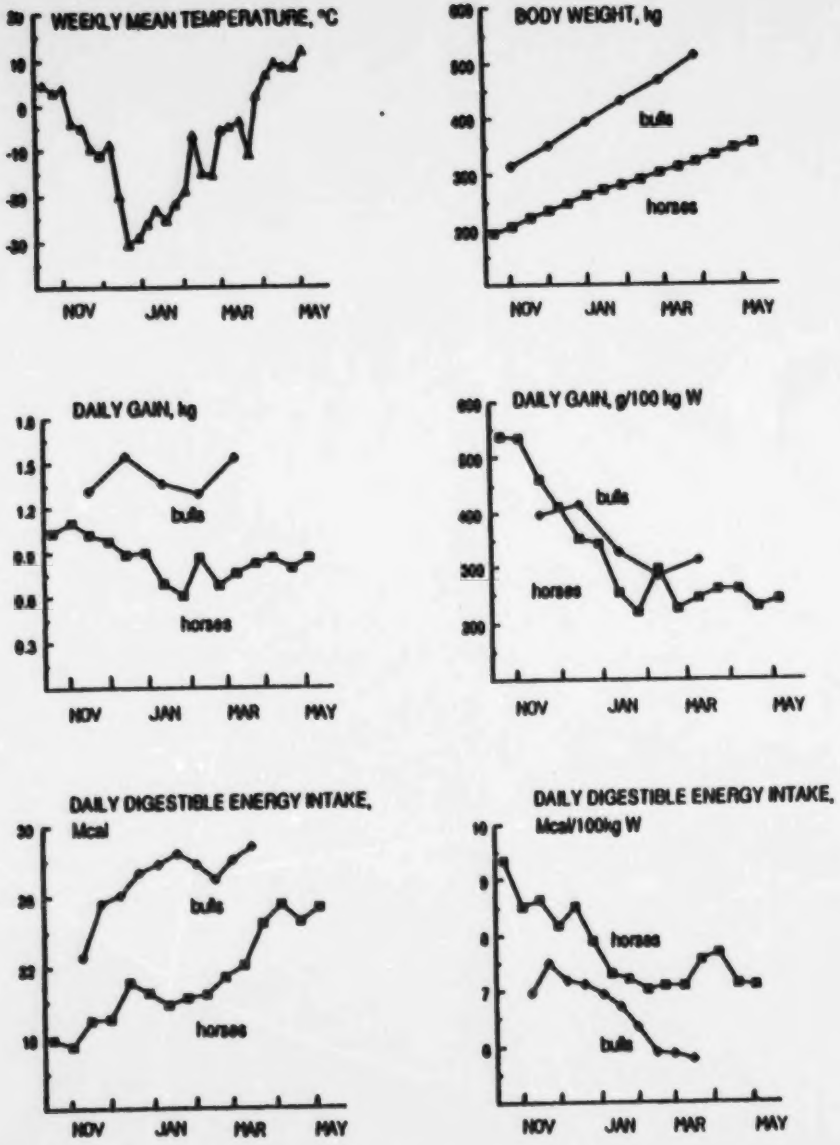

Fig. 1. Weekly temperatures and performance variables of bulls and horses reared outdoors during months of severe cold.

Daily and weight-scaled DE intakes did not differ between the forage and concentrate fed horses, therefore data were pooled to evaluate these variables. Regardless of dietary source, these ad libitum fed horses consumed 37% more DE per day than the amount suggested for growth by NRC (1978). Daily DE intakes by bulls increased with days on test, and hence age and weight, from November to mid-January and decreased slightly in February (Fig. 1). DE intake may have increased as a result of the bitter January cold and the apparent February trough may represent a return to a "normal" intake. Although the horses had positive weight gains throughout the winter, intake plateaued from mid-December to mid-February concurrent with the period of severe cold (Fig. 1).

Correlations of Intake with Days on Test and Temperature

Daily DE intake is an important production variable affecting the animal's ability to meet its requirements for growth and maintenance, including environmental thermal demand. Changes in daily DE intake are metabolically controlled (NRC 1987) and can be related to environmental temperature stress. Because W is one of the main determinants of feed intake (NRC 1987), the data were weight-scaled using 100 kg W. Scaling to $W^{.75}$ did not afford statistical improvement over using W^{1} in agreement with Turner and Taylor (1983) and Fegan and Hintz (1986).

Moderate but significant correlation (r) was found between daily DE intake and number of days the animals had been on test (Table 1). The coefficient of determination was not improved by adding quadratic or cubic terms to the equation. Weight and age effects on DE intake by horses have been discussed in detail elsewhere (Cymbaluk and Christison 1988). When daily air temperature was used as the independent variable, the r value was low for both species. This implies that daily temperature had a smaller association with daily DE intake than did age. The slopes of the equations indicate that 1 C decrease in air temperature caused bulls to increase DE intake by .35% and for horses to decrease DE intake by .32%.

For bulls, weight-scaled DE intake had a higher correlation to days on test than to temperature (Table 1). Days on test is confounded with age and maturity but, nonetheless, time should be considered in climatic trials even when the data are weight-scaled. The slope of the weight-scaled DE intake-temperature equation for bulls indicates that every 1 C decrease in temperature would cause intake to increase by .12%. Thus, if air temperature

Table 1. Regressions of Daily Digestible Energy Intake of Growing Bulls and Horses Against Days on Test and Daily Temperature (°C).

Intake	Species	Model	r
Digestible energy intake (Mcal)	Bulls	24.5 + .0348 Days	.40***
		25.7 - .0907 Temp	.28***
	Horses	17.0 + .0365 Days	.53***
		21.9 + .0711 Temp	.21***
Digestible energy intake (Mcal/100 kg W)	Bulls	7.58 - .01367 Days	.34***
		6.51 - .00781 Temp	.08**
	Horses	8.81 - .00905 Days	.38***
		7.80 + .00559 Temp	.05†

***, ** P<.001, P<.01, respectively
† P=.10

fell from 0 to -15 C, intake would increase by 1.8%. This response is similar to the 4.3% increase derived from 5 years of bull data (Christison et al. 1988). Furthermore, NRC (1981) has indicated that if temperature dropped from 0 to -15 C, total feed intake would increase by 5 to 17%. Thus, acclimatized bulls fed ad libitum change intake minimally in response to severe cold. The pattern of weight-scaled DE intake by bulls up to termination of the study at 140 d was similar to horses. A simple model of weight-scaled DE intake to temperature was not significant (P=.10) for horses (Table 1). However, Fig. 1 and detailed examination of the data for horses (Cymbaluk and Christison 1988) indicated that there was a two-phase response in weight-scaled DE intake across time. Weight-scaled DE intake in horses declined with days on test to day 140 and plateaued until day 210. This biphasic response may reflect a non-specific age effect of acclimatization, increased insulation by fat and coat cover, or seasonal influences. Descriptive models of weight-scaled DE intake in horses indicated that 51% of the effect was due to age, 2% from temperature, 1% from precipitation and 10% from changes in global solar radiation (Cymbaluk and Christison 1988). The effect of temperature in this model was to decrease weight-scaled DE intake by .14% for each 1 C decrease in temperature.

It is notable in the present study that the response by horses to low temperatures was in a direction opposite to that reported for cattle and for other species (NRC 1981). Previous data collected by us indicated that weight-scaled DE intake of horses kept in an unheated barn increased with decreasing temperature to a similar extent as for cattle in the present study (Cymbaluk et al. 1988).

Climatic Ranges

The simple linear model described in Table 1 gives equal value to all parts of the temperature range encountered. However, some effects may occur only at the low end of the temperature range. Thermal environment can affect feed intake above temperatures defined as the lower critical temperature for feedlot steers (Young 1983). The effects of daily temperature, precipitation and wind speed on the adjusted means of weight-scaled DE intake are given in Table 2.

Horses consumed more DE per unit of body weight than cattle irrespective of temperature. When exposed to daily temperatures between -10 and -20 C, bulls consumed 6.64 Mcal/100 kg W which is higher (P<.01) than the 6.49 Mcal/100 kg W consumed above -10 C (Table 2). The 2.3% increase at -10 to -20 C is consistent with the results in the previous section where an air temperature of -15 C was calculated to result in a 1.8% increase in weight-scaled DE intake. Below -20 C the further 1.8% increase in intake by bulls (from 6.64 to 6.76 Mcal/100 kg W) was not statistically significant (P=.06), but suggests that decreasing temperatures may still stimulate intake. DE intake by horses was similar below -20 C and in the -10 to -20 C temperature range (Table 2). These intakes represent a 6.1% decrease from the 7.99 Mcal/100 kg W consumed above -10 C (P<.01).

The species difference in response to severe cold is probably not due to diet composition. Silage, although a bulky feed, was eaten in greater amounts by bulls in response to cold temperatures (Table 2). Horses consumed similar quantities of DE irrespective of whether they were fed forage or concentrate diets. Pelleting of both diets allowed maximization of intake, particularly of the high hay diet. Thus, the hay diet was not a factor limiting intake in horses. Intake of weight-scaled DE declined at low temperatures indicating that other factors than the capacity of the gastrointestinal tract contributed to the cold weather response. Metabolic processes may have been reduced at bitterly cold temperatures. Yet there was no obvious decrease in feeding activity to account for the reduced intake and weight-scaled daily gain (Fig. 1) which occured from February onwards rather than during the cold

Table 2. The Effects of Temperature, Wind and Precipitation on Age-Adjusted Least Square Means for Daily Digestible Energy Intake (Mcal/100 kg W) by Growing Bulls and Horses Fed Ad Libitum.

			Bulls		Horses	
Variable	Range		days[a]	DE/W	days[a]	DE/W
Temperature (°C)	> -10	-	56	6.49[y]	120	7.99[x]
	-10 to -20	-	40	6.64[x]	46	7.53[y]
	< -20	-	44	6.76[x]	44	7.52[y]
Wind (m/s)	< 4.34	-	99	6.63	136	7.75
	≥ 4.34	-	41	6.61	74	7.60
Precipitation (mm/d)	< .25	-	100	6.59	138	7.61
	≥ .25	-	40	6.67	52	7.75
Temperature (°C) and Wind (m/s)	> -10	< 4.34	36	6.47	69	8.01
		≥ 4.34	20	6.51	51	7.96
	-10 to -20	< 4.34	27	6.69	30	7.77
		≥ 4.34	13	6.59	16	7.29
	< -20	< 4.34	36	6.80	36	7.48
		≥ 4.34	8	6.72	8	7.56

[a] Number of days on which the conditions occurred

[x,y] For each species, means associated with different temperature ranges followed by different superscripts differ (P<.01)

period. Alternatively, the warmer temperatures and changes in photoperiod in spring may have stimulated appetite. Exercise was vigorous in the spring. Exercise is a major energy expense in the horse (NRC 1978) and would increase feeding activity.

Above average daily wind speed had no significant effect (P>.05) on weight-scaled DE intake of bulls or horses (Table 2). Both species were protected by wind-break fences and the bulls also had sheds. Since wind had a minimal effect on horses and none in cattle, these types of shelters appear to be effective. Precipitation did not alter intake by either species. Bulls had overhead shelter in the loafing area but were exposed to precipitation when eating. In the absence of strong wind, the powdery snow which falls during severe cold would probably be of little concern to either species when in full winter coat. Lying behavior of the horses did not appear to change during storms. It is unknown whether or not the sheds were necessary for the bulls.

When wind effects were considered in the different temperature ranges, no changes were noted in weight-scaled DE intake except for the horses at -10 to -20 C when intake decreased at higher wind speeds. Lower critical temperatures for young and adult horses are predicted to be -1 and -15 C, respectively (Young and Coote 1977); McBride et al. 1985), during mild winters, but acclimatization may alter these limits. It may be that our horses were not yet fully acclimatized to severe cold during the periods when temperatures were initially between -10 to -20 C. Wind at these temperatures would effectively lower ambient temperature and consequently reduce feed intake. When temperatures of -20 C and below occured, acclimatization and an

increase in body insulation (hair coat depth, body fat) may have minimized the effects of wind. Climatic effects would be more severe on the horses because they did not have overhead shelter and were therefore exposed to greater precipitation, less dry bedding and greater radiant heat losses to the clear sky. Yet it appears that full-fed horses can tolerate severe temperatures with little effect. Thus, the types of shelter provided for the two species were adequate for acclimatized animals fed ad libitum.

Behavior

Subjectively, it appeared that the horses were always more active than cattle in adjacent pens. Play fighting and playing activities by horses continued during dry, very cold temperatures but was reduced by snowfall. Feeding activity was not obviously reduced by bitterly cold temperatures.

CONCLUSIONS

Beef bulls responded to severe cold temperatures by elevating DE intake. Horses responded to similar temperature extremes by reducing DE intake. Horses consumed more DE per unit of body weight than cattle irrespective of the ambient temperature. Age, and thus body weight, confounded the weight-scaled DE intake response to temperature by both species. Scaling DE intake to W^{1} showed that bulls ate .12% less DE per 100 kg W for each degree decline in temperature below 0 C and increased weight-scaled DE intake by 1.8% at -15 C. Temperature was poorly related to weight-scaled DE intake by horses. DE intakes by horses were 6.1% lower below -10 C than at temperatures above -10 C. By comparison, bulls ate 2.3 or 4.1% more DE/100 kg W at -10 to -20 C and below -20 C, respectively, than at temperatures above -10 C. Growth of bulls and horses was comparable to values reported for these types of livestock reared in other regions of the world. Cattle and horses are able to tolerate severe cold temperatures if sheltered from wind and given readily digested feeds free choice.

ACKNOWLEDGEMENTS

The project was supported by the Saskatchewan Agriculture Research Fund and the Farming for the Future program of Alberta Agriculture. The technical assistance of F. E. Teitge and J. A. de Gooijer and the provision of climatic data by R. Degrand of the Saskatchewan Research Council are gratefully acknowledged.

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